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Energy Options for Water Desalination in UAE

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Abstract

The aridity, population growth, agriculture and industrial activities threaten the water resources in the UAE. In UAE, groundwater quantity is reduced and its quality is also deteriorated due to the scanty of rainfall and over pumping for different uses. The deficit of groundwater is met by desalinated water and reused of treated wastewater. To improve the current water situation, a national water resources strategy has been prepared and implemented to assist in achieve this target and maintain the country's water security. This paper intends to give an overview of non-conventional energy technologies for water desalination. These include solar, fossil fuel, and nuclear technologies. Using simplified score model analysis, options were evaluated for best water uses considering water productivity and environmental sustainability criteria. It was concluded that solar technologies are most effective for water desalination in UAE. However, oil, natural gas and nuclear technologies have low likelihood to be viable in the short term.

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Keywords: Desalination; Solar energy; Nuclear energy; Simplified Scoring Model; UAE.

1. Introduction

The shortages of water resources in the UAE became a big concern in arid and semi-arid zones. Fears and anxieties are increasing due to heavy abstractions of conventional water resources for mainly agricultural activities.

UAE is located within the arid zone to the southeastern part of Arabian Peninsula. The arid zone is characterized by low amount of rainfall and high rate of evaporation. Its climate and scarce rainfall make it difficult for the UAE to sustain potable water production by means other than desalinating seawater. This involves vaporizing and re-liquefying seawater in plants powered by natural gas and liquefied natural gas, and sometimes diesel.

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About 40 percent of supply is supported by 70 desalination plants. More than half comes from groundwater sources, but these are mainly used for irrigation as just 3 per cent can be classified as drinkable due to salt water intrusion, according to the UAE Ministry of Environment and Water. Around 9 per cent is treated wastewater[1].

The ministry predicts that at current rates the UAE's total annual water demand will double to 8.8 billion cubic meters by 2030 from 4.4 billion cubic meters in 2008. The greatest increase will be in urban centers, in households, the industrial and commercial sectors and public facilities. According to the UAE Water Conservation Strategy, desalination and wastewater treatment will have to increase to satisfy growing demand, with the so-called reclaimed water making up a far larger share in the future. Experts say this should go in tandem with strategies to save water. The UAE has the highest per capita consumption rate in the world at around 550 liters a day, more than three times that of Europe.

The UAE pumped nearly 1.7 billion cubic meters (bcm) of desalinated water in 2011 to become the second largest desalination producer in the world after Saudi Arabia. The level produced last year was the highest to be pumped by the UAE as more sea desalination plants have been set up and existing units have been expanded to face a steady growth in domestic demand. A water gap in the Gulf countries could sharply widen in 2030 in the absence of major desalination projects to meet a rapid increase in consumption because of a steady growth in the region's population and economic expansion.

The UAE with five other Gulf hydrocarbon producers, suffered from a water supply gap of around 15 bcm in 2008 and the deficit could soar to nearly 35 bcm in 2030. Demand in the UAE averages as high as 360 liters a day per individual and that Abu Dhabi has the highest consumption rate, standing at more than 550 liters per individual compared with 200 liters in Sharjah[1].

2. Energy Resources in UAE

The United Arab Emirates is one of the 10 largest oil and natural gas producers in the world, and is a member of the Organization of the Petroleum Exporting Countries (OPEC) and the Gas Exporting Countries Forum (GECF).It is a major oil producer and exporter. In 2012, the country produced an average of 2.8 million barrels of crude oil per day; the eighth highest total in the world. The United Arab Emirates appears unlikely to meet a 3-million-barrel-per-day crude oil production target by the end of 2013. Further, the country may push back a longer-term 3.5 million barrel per day target until the end of the decade. The UAE has one of the highest rates of per capita petroleum consumption in the world. The UAE plans to boost domestic natural gas production over the next several years to help meet growing internal demand. Much of the growth could come from the country's large sour (high sulfur) gas deposits. Already a top-20 global natural gas producer, the UAE has several ongoing projects that could boost the country's natural gas production significantly over the next several years. The United Arab Emirates was the first country in the Middle East to export liquefied natural gas (LNG), and has exported more than 250 billion cubic feet of LNG annually, almost exclusively to Asia[2].

The UAE is adding nuclear, renewable, and coal-fired electricity generating capacity, but currently relies primarily on natural gas. The UAE holds the seventh-largest proved reserves of oil in the world at 97.8 billion barrels, with the majority of reserves located in Abu Dhabi (approximately 94% of the UAE's total). The other six Emirates combined account for just 6% of the UAE's crude oil reserves, led by Dubai with approximately 4 billion barrels. The UAE holds approximately 6% of the worlds proved oil reserves[2].

The UAE holds the seventh-largest proved reserves of natural gas in the world, at just over 215 trillion cubic feet (Tcf). Despite its large endowment, the UAE became a net importer of natural gas in 2008. This phenomenon is a product of two things:(1) the UAE re-injected approximately 26% of gross natural gas production from 2003 to 2012 into its oil fields as a part of EOR techniques, and (2) the country inefficient and rapidly-expanding electricity grid.

Despite holding some of the largest deposits of hydrocarbons in the world, the UAE is planning to diversify its energy mix beyond hydrocarbon-based electricity generation, including nuclear and renewable-energy technologies. In December 2009, the UAE awarded a $20 billion contract to the Korea Electric Power Corporation (KEPCO) to construct four nuclear reactors, and in July 2012 the licenses were approved for KEPCO to begin construction on the first two 1,400-megawatt reactors. The first reactor is scheduled to come on-line in 2017, with the others expected to be completed by 2020. Upon completion of the first reactor, the UAE will become the second country in the region (after Iran) to have a domestic nuclear program. To avoid concerns about their use of nuclear technologies, the UAE sought—and received—International Atomic Energy Agency (IAEA) approval for its nuclear project, and committed itself to forgoing the domestic enrichment and reprocessing of nuclear fuel by signing a law that banned that practice within the country. In addition, the UAE signed a nuclear cooperation agreement with the United States in 2009, and it is a signatory of the Nuclear Non-Proliferation Treaty.

The UAE is also investing in renewable energy technologies, most notably through the Masdar initiative. Established in 2006, Masdar is a subsidiary of Abu Dhabi's state-owned Mubadala Development Company, and is focused on being a leader in the development of renewable and sustainable energy technologies. Masdar City is the flagship project of the initiative, and aims to be the world's first zero-carbon city. It already houses the Masdar Institute—a joint effort between the Massachusetts Institute of Technology and Masdar— and plans are in the works to bring hundreds of other high-technology and renewable energy businesses into the city over the coming years.

Masdar announced plans to develop the Sir Bani Yas wind farm—with a target capacity of 28.8 megawatts (MW)—and the Shams[1] concentrated solar power (CSP) plant (100 MW capacity) over the next several years, and should continue to help the UAE find new ways to diversify its energy mix. This progress recently helped spur the International Renewable Energy Agency (IRENA) to establish its headquarters in Abu Dhabi. The UAE is supporting the deficit in conventional water resources with the conventional water resources and in particular the desalination of seawater and brackish water.

3. Desalination in UAE

The desalination technology started in UAE in 1976, when the first plant was established in Abu Dhabi with a capacity of 66000 gallons/day. The establishment of desalination plant since that time indicates that the water scarcity is an old problem and the severity of this problem is increasing annually. Over the time, the water demand for domestic, agricultural and industrial is increasing, so new desalination plants are being constructed in the country. A total of 36 desalination plants were built in UAE by the end of 2006. Beside this, there were 10 main desalination stations belonging to FEWA and operating in the northern and eastern parts of the country. Also, there were 8, 5 and 12 main desalination stations in Abu Dhabi, Dubai and Sharjah, respectively. In addition, there were 2 plants to desalinate groundwater in Umm Al Quwain[1].

The production of desalinated water is increasing over the time to provide sufficient quantities of water for different activities. Since 2000, the UAE continued to depend on groundwater and treated water besides desalinated water to meet the increased demand of water for different purposes. The total production of desalinated water in UAE was 134412.8 million gallons in 2000 and it increased to 277942.14 million gallons in 2006. The increased of desalinated water production observed in all emirates. The desalination production is higher in Abu Dhabi and Dubai due to economic developments in both emirates and rapid immigrants to Abu Dhabi and Dubai seeking the political stability[1].

The dependency of desalinated water for all emirates is higher than groundwater and the percentages of dependence are increased significantly due to the shortages of groundwater. Water production by ADWEA is mainly depending on desalination and its dependency increased from 85.95% in 2000 to 99.73% in 20006. Also, the water production of DEWA is mainly desalinated water with dependence percentage of 95.7% in 2006 comparing with 93.73% in 2000. However, the dependency of desalinated water of SEWA and FEWA in 2000 was 52.78% and 35.02% and it increased to 66.22% and 62.11% in 2006, respectively It is obvious that the eastern and northern emirates of the country are depending in both groundwater and desalinated water, whereas both Abu Dhabi and Dubai Emirates mainly rely on desalinated water. The production of groundwater in eastern and northern emirates is relatively high due to the closeness from recharge area, but the dependency in groundwater in those areas will decrease with the time and depend on desalinated water will increase to cover the deficit on groundwater as the population of the country is increasing rapidly[1].

The UAE is planning a 68,000 m^3/day plant at Ras Al Kaimah. Sembcorp is expanding the Fujairah 1 136,000 m^3/day RO plant, to bring its UAE capacity to 591,000 m^3/day of which 307,000 is RO and 284,000 m^3/day is MSF. Also the Shuweihat S2 IPP and seawater diesel plant at Al Ruwais started full operation in 2011 and provides 1510 MWe and 454,000 m^3/day by MSF. The Fujairah[2] plant is hybrid SWRO-MED and produces 454,600 m^3/d. The

Taweelah A1 cogeneration plant produces 1430 MWe and 385,000 m^3/day and Umm Al Nar produces 394,000 m^3/day. The 136,400 m^3/day Al Zawra seawater desal plant is to be built at Ajman.

In Dubai the Jebel Ali M cogeneration plant opened in 2013 with 6x243 MWe gas turbines and 8 MSF units providing 640,000 m^3/day. Earlier, Dubai invited bids for constructing a 450,000 m^3/day (165 GL/yr) seawater desalination plant as part of its Hassyan independent power project, but then announced its deferral.

Renewable energy sources are able to be used for desalination more readily than for most electricity supply, since the product can be stored on any scale, unlike electricity. Also electricity can be borrowed from the grid and repaid when the wind is blowing or the sun shining. A 45 GL/yr RO plant at Perth, Western Australia is powered by electricity ostensibly from a wind farm. A new 100 GL/yr RO plant is powered by 65 MWe of dedicated renewable energy (10 MWe solar PV, 55 MWe wind)[3].

4. Results and Discussion

In this paper we assist decision-makers to evaluate the use of conventional and non-conventional energy sources for water desalination in UAE. The evaluation will be based on the Simplified Scoring Model; non-financial model.

Four types of energy sources have been selected to be evaluated which are: solar, oil, natural gas and nuclear energy. There are two different performance aspects have been decided to be analyzed Cost performance and benefit performance. In each aspect there are some criteria listed to be used as comparison criteria among various selected energy sources.

The financial evaluation of non-conventional energy sources for water desalination systems is conducted using one of the most known conventional methods, such as Net Present Value (NPV) or Internal Rate of Return (IRR). The socio-economic evaluation makes assessments to all gains (benefits) and all losses (costs) of non-conventional energy sources for water desalination systems which include the financial, social, cultural and ecological impacts. The most widely used method in socio-economic analysis is the cost-benefit analysis. Although the assessment of socio-economic benefits and costs depends first of all on the data provided by the cash flow sheets, it is supplemented by socio-economic impacts from the field of welfare economics. Non-financial evaluation of different energy and water systems has been used by many authors[4,5,6,7,8,9,10,11,12,13,14,15].

4.1. Simplified Scoring Model

In the simplified scoring model, each criterion is ranked according to its relative importance. Our choice of an option will reflect our desire to maximize the impact of a certain criterion on our decision. In order to score our simplified checklist, we assign a specific weight to each of our five and seven criteria. Thus, the simple scoring model consists of the following steps:

- Assign importance weight to each criterion.
- Assign score values to each criterion in terms of its rating (High =3, Medium = 2, Low =1).
- Multiply importance weight by scores to arrive at a weighted score for each criterion.
- Add the weighted score to arrive at an overall option score.

In evaluating the option of energy technology to be used for water desalination in UAE, the benefit and cost were analyzed separately, the overall objective for both is to select an optimum energy technology for water desalination in UAE. The cost criteria include the cost of fuel, hardware cost, maintenance cost, auxiliary system cost, and environmental constraints, while the benefits criteria are efficiency, reliability, availability of fuel, national economy, social benefits, system safety, and economical interest.

Thus, the measurement of potential benefits from a particular energy technology option exceeds, in scope, the financial return on that option and encompasses its contribution to the overall benefit of the nation. These socio-economic gains are represented by the criteria of the national economy, economical interest, and social benefits.

All items in the cost criteria can be related in terms of cost or money value, a part from one item, which is very difficult to quantify in terms of money, namely, environmental constraints, which measures the effect of using an energy technology option for water desalination on the environment, directly or indirectly.

4.2. Cost Performance Matrix

Assuming that evaluations of high receive a score of *high* 3, *medium* 2, and *low* 1.

Assessment Criteria:	Importance Weight
1. Cost of fuel	4
2. Hardware cost	3
3. Maintenance cost	4
4. Auxiliary cost	1
5. Environmental constraints	2

Table 1. Cost Performance Matrix.

Source of Energy	Criteria	(A) Importance Weight	(B) Score	(A)x(B) Weight Score
Solar Desalination	Cost of Fuel	4	1	4
	Hardware Cost	3	3	9
	Maintenance Cost	4	1	4
	Auxiliary System	1	3	3
	Environmental Constraints	2	1	2
			Total Score	22
Oil Desalination	Cost of Fuel	4	1	4
	Hardware Cost	3	2	6
	Maintenance Cost	4	2	8
	Auxiliary System	1	1	1
	Environmental Constraints	2	3	6
			Total Score	25
Natural Gas Desalination	Cost of Fuel	4	2	8
	Hardware Cost	3	2	6
	Maintenance Cost	4	2	8
	Auxiliary System	1	1	1
	Environmental Constraints	2	3	6
			Total Score	29
Nuclear Desalination	Cost of Fuel	4	3	12
	Hardware Cost	3	3	9
	Maintenance Cost	4	3	12
	Auxiliary System	1	1	1
	Environmental Constraints	2	3	6
			Total Score	40

4.3. Benefit Performance Matrix

Assuming that evaluations of high receive a score of *high* 3, *medium* 2, and *low* 1.

Assessment Criteria:	Importance Weight
1. System Efficiency	3
2. System Reliability	4
3. Availability of Fuel	4
4. National Economy	3
5. Social Benefits	2
6. System Safety	2
7. Economical Interest	3

Table 2. Benefit Performance Matrix.

Source of Energy	Criteria	(A) Importance Weight	(B) Score	(A)x(B) Weight Score
Solar Desalination	System Efficiency	3	1	3
	System Reliability	4	1	4
	Availability of Fuel	4	3	12
	National Economy	3	2	6
	Social Benefits	2	2	4
	System Safety	3	3	9
	Economical Interest	3	1	3
			Total Score	41
Oil Desalination	System Efficiency	3	1	3
	System Reliability	4	2	8
	Availability of Fuel	4	3	12
	National Economy	3	3	12
	Social Benefits	2	2	4
	System Safety	2	2	4
	Economical Interest	3	2	6
			Total Score	37
Natural Gas Desalination	System Efficiency	3	1	3
	System Reliability	4	2	8
	Availability of Fuel	4	2	8
	National Economy	3	3	9
	Social Benefits	2	2	4
	System Safety	2	2	4

	Economical Interest	3	2	6
			Total Score	42
Nuclear Desalination	System Efficiency	3	2	6
	System Reliability	4	3	12
	Availability of Fuel	4	1	4
	National Economy	3	3	9
	Social Benefits	2	3	6
	System Safety	2	1	2
	Economical Interest	3	3	9
			Total Score	48

According to the cost evaluation score model solar desalination is the best option and the worst one is the nuclear desalination. On the other hand, according to the benefit evaluation nuclear desalination is the best option, while using oil as a source of energy for desalination is the worst option; the lowest benefit score.

5. Conclusion

Fresh water is a major priority in sustainable development. Where it cannot be obtained from streams and aquifers, desalination of seawater or mineralized groundwater is required. An IAEA study in 2006 showed that 2.3 billion people live in water-stressed areas, 1.7 billion of them having access to less than 1000 m^3 of potable water per year. With population growth, these figures will increase substantially. Further demand in the longer term will come from the need to make hydrogen from water.

Water consumption in the UAE and other regional countries is among the highest in the world because of the hot weather, a rapid rise in the population, waste habits and other factors. So we should recover this shortage by thinking of sea water desalination plants and select the best source of energy in operating them.to Jordan's severe water scarcity, it must.

Based on the analysis we can conclude that use of solar energy in desalination is the best option. Oil and Natural gas is somewhat feasible at current time. On the other hand, nuclear energy is to be considered for the long term in UAE. Further research and studies in this area are needed to ensure technical and economic feasibility of each technology.

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